



STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 1 of 21
REV: 0.0
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OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

CONTENTS

1.0	SCOPE AND APPLICATION
2.0	METHOD SUMMARY
3.0	SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE
4.0	INTERFERENCES AND POTENTIAL PROBLEMS
5.0	EQUIPMENT/APPARATUS
6.0	REAGENTS
7.0	PROCEDURES
7.1	Instrument Controls and Power Source
7.1.1	Front Wall - Base Unit
7.1.2	Back Wall - Base Unit
7.1.3	Rear Left Side Wall - Base Unit
7.1.4	Rear Right Side Wall - Base Unit
7.1.5	Top Wall - Base Unit
7.1.6	Power Source
7.2	Entering PARAMETERS
7.3	Pre-Operational Checks
7.4	TEST Mode
7.5	ON STREAM (Air Analysis) Mode
7.6	HIGH CONCENTRATIONS Mode
7.7	Operation with a Personal Computer
8.0	CALCULATIONS
9.0	QUALITY ASSURANCE/QUALITY CONTROL
10.0	DATA VALIDATION
11.0	HEALTH AND SAFETY



STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 2 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915+ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

CONTENTS (continued)

12.0 REFERENCES

13.0 APPENDICES

A - Figures

B - Maintenance, Troubleshooting, Storage, and Transportation

C - Test Cell Mercury Concentration vs. Temperature

STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 3 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the operation, maintenance, and functional test procedures of the Ohio Lumex Company, Inc., Model RA-915⁺ Mercury Analyzer for the determination of mercury vapor in ambient air. Refer to the Lumex RA-915⁺ User's Manual for detailed operating procedures.

The Lumex RA-915⁺ is applicable for screening ambient and indoor air for mercury in units of nanograms of mercury per cubic meter of air (ng Hg/m³). This instrument may be used to quantify mercury levels for site assessment as well as health and safety surveys.

2.0 METHOD SUMMARY

The RA-915⁺ is battery operated and the operating principle is based on the effect of differential Zeeman atomic absorption spectrometry combined with high-frequency modulation of polarized light.

The radiation source (mercury lamp) is positioned in a permanent magnetic field. The resonance mercury line at [254 nanometers (nm)] is split into three polarized Zeeman components: π , σ_+ , and σ_- respectively). When radiation is observed along the magnetic field lines, only the σ component radiation is registered. One σ component is within the mercury absorption line envelope and the other is outside it. In the absence of mercury vapor, the intensity of both σ components is equal. Mercury atoms cause a proportional, concentration-related difference in the intensity of the σ components. A polarization modulator is used to separate the σ components in time. Because the spectral shift of the σ components is significantly smaller than the width of molecular absorption bands and scattering spectra, the background absorption caused by interfering components generally does not affect the analyzer measurement. A multi-path cell with an effective length of 10 meters (m) is used to enhance the sensitivity of analysis.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

This section is not applicable to this SOP.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

Never expose the analyzer to metallic mercury! Any direct contact of any part of the instrument with metallic mercury will result in high background noise for a prolonged period of time. Avoid long operation with the multi-path cell in areas with high mercury vapor concentration (higher than 10,000 ng/m³). Use the HIGH CONCENTRATIONS measuring mode for these cases. Unknown interferences due to the presence of other contaminants may adversely affect mercury vapor measurement results.

While taking measurements of mercury concentrations in ambient air, observe basic safety regulations dealing with mercury and its compounds, mercury-filled devices, and operating codes and safety regulations for electrical installations.

STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 4 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915+ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

The basic RA-915+ analyzer is not intrinsically safe and should not be operated in an explosive atmosphere. Refer to the RA-915+ User's Manual for additional safety guidelines.

Only personnel trained in the use of this analyzer is authorized to take measurements and process their results.

5.0 EQUIPMENT/APPARATUS

The following equipment is required for the operation of the Lumex RA-915+ Mercury Analyzer:

- Base unit
- Display and control unit
- Removable air intake hose with pre-filter
- Display unit connector cable
- Power supply unit, for alternating current (AC) operation and battery charging
- Spare parts and accessories kit
- User's Manual
- Canvas shoulder bag

The analyzer may also be controlled and operated using a computer and interface cable (Section 7.7).

6.0 REAGENTS

This section is not applicable to this SOP.

7.0 PROCEDURES

7.1 Instrument Controls and Power Source

7.1.1 Front Wall - Base Unit

- Inlet 1 opening (containing a dust filter) for ambient air into the multi-path cell;
- Inlet 2 opening (containing a built-in absorption filter) for ambient air into the multi-path cell;

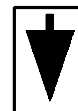


STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 5 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915+ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

- Outlet opening for the multi-path cell;
- Analyzer power switch;
- Main power supply connector;
- Ignition button for the spectral lamp (LAMP IGNITION); and
- Light diodes indicating built-in battery status: charged or discharged



7.1.2 Back Wall - Base Unit

- Auxiliary compartment containing the single-path analytical cell, to be used with the RP-91 attachment for determining mercury in solutions, and for HIGH CONCENTRATION mode;
- Retainer screw for mounting attachments;
- Handle for optical bridge three position switch providing light path through different analytical cells:

position I: external analytical cell

(to be used with the RP-91C attachment to determine mercury in solid samples)

position II: single-path cell

(auxiliary compartment)

position III: multi-path cell

7.1.3 Rear Left Side Wall - Base Unit

- TEST handle for positioning the test cell when checking analyzer serviceability. The OFF position means that the test cell has been taken out of the optical path, while ON means that the test cell is in the optical path.

7.1.4 Rear Right Side Wall - Base Unit

- Opening for attaching the RP-91C optical block

7.1.5 Top Wall - Base Unit

- RS 232 connector for the display and control unit or a computer interface cable

7.1.6 Power Source

The power source may be selected as summarized in the following table:

STANDARD OPERATING PROCEDURES

SOP: 1729

PAGE: 6 of 21

REV: 0.0

DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

POWER (toggle)	Outer Power Source	Battery Indicator		OPERATING MODE
		Charged	Discharged	
OFF	ON			Analyzer is off Built-in Battery is charging
ON	OFF	OFF	Flashes	Operation from built-in battery
	OFF	OFF	ON	Built-in battery is discharged
	ON	Flashes	OFF	Operation from AC 110 V mains and built-in battery is charging
	ON	ON	OFF	Operation from AC 110 V mains

The frequency of flashes and duration between flashes of the front panel "charged" / "discharged" indicators represent battery power status. While working with mains supply, the more the battery is charged, the longer the flash duration for the "charged" indicator lamp. With battery power, the more the battery is discharged the longer the flash duration for the "discharged" indicator lamp.

If only the battery needs to be recharged (no measurements need to be taken), do not switch the mercury lamp on. To recharge the battery under these conditions, connect the charging unit and shut the POWER switch OFF. Recharging time for a completely discharged battery is 5 hours. No indicator lamps will flash or light on the panel. The green light will stay ON when the battery is fully charged and the power switch is turned back to the ON position.

Overcharging does not cause any loss of battery performance. A fully charged battery provides continuous operation for approximately 3.5 hours. Charge the battery on a timely basis. Store the unit with the battery fully charged. Storage of a fully discharged battery for 3 days may permanently damaged the battery.

7.2 Entering PARAMETERS

A backlit display is mounted on the top of the display unit face panel to indicate signals, parameters and operation modes. Use the **Ent**, **Esc**, **←**, **↑**, **→**, **↓** buttons to select the measurement modes and parameters.

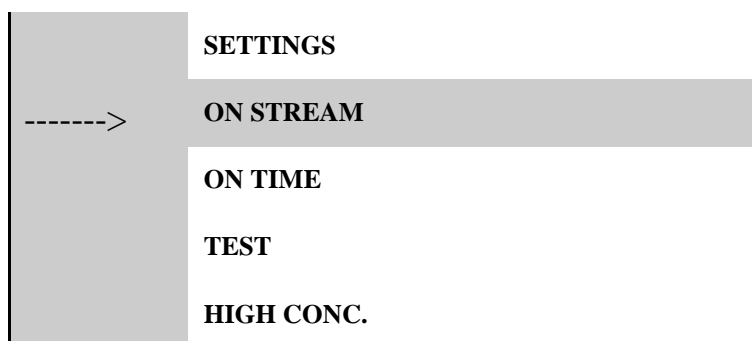
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MAIN MENU

STANDARD OPERATING PROCEDURES

SOP: 1729
 PAGE: 7 of 21
 REV: 0.0
 DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR



SETTINGS mode (parameters settings). Change the language if desired. The ranges for operation mode parameters and their default values are shown in the table below. Use the default values or set parameters according to site conditions and requirements. After setting parameters, press the **Esc** button to save parameter values or to restore the defaults.

PARAMETERS	Designation	Range	Default Value
Base correction time, sec (zero)	t_{zero}	1 - 255	20
Frame time, sec	t_{accum}	10 - 255	10
Integration time, sec	t_{int}	1 - 255	150
Low Limit, ng/m ³	LL	1 - 255	20
High Limit, ng/m ³	HL	1 - 10000	100

7.3 Pre-Operational Checks

The following checks must be performed prior to the operation of the RA-915⁺ analyzer for determining concentrations of mercury in ambient air:

1. Conduct a visual inspection of the analyzer's component parts. Check to ensure that all components are present and for any signs of external damage to RA-915⁺ components.
2. Place the analyzer in an up-right (vertical) position. The display unit is on top.
3. Install the display and control unit directly in the base unit or use a cable to connect it.
4. Set the TEST cell control handle to the OFF position.

STANDARD OPERATING PROCEDURES

SOP: 1729
 PAGE: 8 of 21
 REV: 0.0
 DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

5. Set the optical bridge switching handle to position III (light passes through the multi-path cell).
6. Switch the RA-915⁺ analyzer on. The display and control unit then shows the manufacturer's trademark.
7. Press the Ent button on the indication and control unit. The display highlights MAIN MENU.
8. Press and hold for several seconds the LAMP IGNITION button on the front panel. When the lamp switches on, the "*" in the top left-hand corner of the display disappears.
9. Wait at least 20 minutes for the analyzer to warm up after switching it on.

7.4 TEST Mode

After performing the pre-operational checks and allowing the instrument to stabilize, use the TEST mode to verify that the analyzer is reading the correct mercury concentration in the test cell. This test must be performed at least once per day and the results must be documented.

1. Set the TEST handle to the OFF position.
2. Select the analyzer serviceability control mode (TEST) and press the Ent button. The SET OPTICAL BRIDGE TO POSITION III message will be displayed.
3. Set the optical bridge to position III and press the Ent button. This switches the compressor on, and the zero signal is measured during the t_{zero} time.
4. The analyzer then switches over to the mode for the introduction of the test cell and the display shows the message Enter Test Cell.
5. Set the test cell selector handle (TEST) to the ON position, wait 10 to 20 seconds, and press the Ent button. The following is displayed:

TT		
	S	1000
	S _k	1200

STANDARD OPERATING PROCEDURES

SOP: 1729
 PAGE: 9 of 21
 REV: 0.0
 DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

	S_i	1100
R(%) =	10	20

where:

S = Current value in ng/m^3 , which is proportional to the mercury concentration in the test cell

S_k = Calculated value corresponding to test cell temperature (Appendix C)

S_i = Mean value, which is the mean mercury vapor concentration determined during the accumulation time, t_{accum}

%R = Percent relative deviation for the measured values S_i compared to the S_k value according to $\%R = 100 \cdot (S_i - S_k) / S_k$

20 = Countdown time in seconds from t_{accum} to 0

The warning message, Temperature, is displayed if the temperature of the test cell is beyond the range for proper operation of the analyzer.

6. If the %R of the measured value S_i from the expected value is less than (<) 25%, the RA-915⁺ analyzer is ready for operation. If it is outside this criterion, refer to Appendix B for maintenance information.
7. To quit the TEST mode, press the Esc button; the analyzer switches to the standby mode for removal of the test cell. The display shows the message Remove Test Cell. Remove the test cell (handle to OFF position) and press the Ent button. The analyzer switches to the MAIN MENU.

7.5 ON STREAM (Air Analysis) Mode

After verifying proper analyzer operation with the TEST mode, analyze ambient air samples using the ON STREAM mode.

1. Ensure that the TEST handle is in the OFF position.

STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 10 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

2. In the PARAMETERS menu, set measurement mode parameters according to site requirements.
3. Select the ON STREAM mode from the MAIN MENU and press the **Ent** button. This switches the compressor on, the zero signal is measured during the t_{zero} time.
4. The SET OPTICAL BRIDGE TO POSITION III message will be displayed. Set the optical bridge handle to position III and press the Ent button.
5. On completion of the zero-signal measurement, the ON STREAM mode screen will appear:

SM	ng/m ³
S = (+/-) 213	
S _i = 209	
10	

Where:

S = Current value (ng/m³) corresponding to mercury concentration;

S_i = Mean value corresponding to the value S averaged over the accumulation time, t_{accum} ;

10 = Countdown in seconds from t_{accum} to 0;

SM = ON STREAM measurement mode;

ng/m³ = Measurement units

The warning message, ALARM, will be displayed if the mercury concentration exceeds the high limit parameter.

STANDARD OPERATING PROCEDURES

SOP: 1729
 PAGE: 11 of 21
 REV: 0.0
 DATE: 08/20/04

OPERATION OF THE LUMEX RA-915+ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

6. If the Ent button is pressed during ON STREAM operation, the unit switches to PROTOCOL mode. This mode is recommended for determination of mercury vapor concentration in indoor air.

SM	ng/m ³		
		S =	(+/-) 213
1	200		
2	210		
3	220		
		S _i =	209
S _{av} =	210		
R(%) =	10		10

Where:

S = Current value, which is the mercury vapor concentration in the pumped air;

S_i = Mean value, the value S averaged over the accumulation time, t_{accum};

10 = Countdown in seconds from t_{accum} to 0;

SM = ON STREAM measurement mode;

ng/m³ = Measurement units

1,2,3 = Three consecutive measurement results S1, S2, S3;

S_{av} = Resulting average value (S1+S2+S3)/3;

%R = Percent relative deviation of the three measurements

$$R(\%) = 100 * (\max(S1, S2, S3) - \min(S1, S2, S3)) / S_{av}$$

If S_{av} is less than the low limit parameter, a relative deviation value is not displayed.

STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 12 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

7. To quit this mode, press Esc. The air pump switches off and the analyzer switches to the MAIN MENU.

7.6 HIGH CONCENTRATIONS Mode

The HIGH CONCENTRATIONS mode is intended for the determination of mercury vapor in atmospheric air when the concentration exceeds 500 ng/m³. In this case, the mercury vapor concentration is measured in the single-path cell compartment with the air pump idling; air is exchanged by convection only. When this mode is selected, a screen similar to that for the ON STREAM mode is displayed except for the name of the operation mode. For this mode, zero control is accomplished by placing a closed small cell in the compartment at the back panel of the analyzer (Section 7.1.2). This cell should be filled with air, which has mercury vapor concentration less than 500 ng/m³. If such a cell is unavailable, the zero signal can be measured using ambient outdoor air.

7.7 Operation with a Personal Computer

This section contains basic instructions for operating the analyzer with a personal computer (PC). For detailed procedures, refer to the separate manual entitled "Analyzer RA-915⁺ User's Manual: Operation With a PC".

1. Ensure that the RA-915⁺ unit is on and is connected to the PC. Start running the RA-915⁺ program.
2. Select the AIR mode in the Main Menu. The Air Analysis screen will appear.
3. Press the LAMP IGNITION button on the front panel of the analyzer. The analyzer is now ready for operation.

NOTE: The LOW INTENSITY warning in the upper right corner of the PC screen indicates that the lamp radiation intensity is insufficient for measurement. After pressing the LAMP IGNITION button, this warning will disappear and the operator should perform the following serviceability check:

1. Set the TEST handle to the OFF position.
2. Select the Test mode button in the Air Analysis screen on the PC. Two black lines will appear on the graph and the current readings will be displayed.
3. Set the TEST handle to the ON position. The signal (obtained when the test cell is installed) will appear on the graph.

NOTE: If the signal (obtained when the test cell was installed) falls within the area between the two black

STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 13 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

lines, the unit is ready for measurements.

8.0 CALCULATIONS

The RA-915⁺ Mercury Analyzer is a direct reading instrument. The readings are displayed in units of ng/m³ and encompass the range 20 to 20,000 ng/m³ for ambient air.

9.0 QUALITY ASSURANCE/QUALITY CONTROL

The following general QA/QC procedures apply:

1. All data must be documented on field data sheets or in site logbooks.
2. The instrument must be operated according to the operating instructions supplied by the manufacturer, unless otherwise specified in the work plan. Instrument checkout activities must occur prior to operation (section 7.3) and they must be documented.
3. The TEST mode (section 7.4) and/or other procedures must be used to ensure the accuracy and precision of mercury measurement in ambient air by the Lumex RA-915⁺ as specified by the manufacturer. The %R must be <25% and all verification procedures must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP; however, the analyst will ensure that the analyzer was operated in accordance with this SOP and that all operational checks have been completed and within the criterion specified.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, refer to the United States Environmental Protection Agency (U.S. EPA), Occupational Safety and Health Administration (OSHA), and corporate health and safety practices. More specifically, refer to REAC SOP #3013, *REAC Laboratory Safety Program*.

The analyst should consult all appropriate material safety data sheets (MSDS) prior to running an analysis for the first time.

12.0 REFERENCES

Ohio Lumex Co., Inc., 2001. *Mercury Analyzer RA-915+ User's Manual*.

Ohio Lumex Co., Inc., 2001. *Analyzer RA-915+ User's Manual: Operation With a PC*.



STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 14 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

13.0 APPENDICES

- A - Figures
- B - Maintenance, Troubleshooting, Storage, and Transportation
- C - Test Cell Mercury Concentration vs. Temperature



STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 15 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

APPENDIX A

Figures
SOP #1729
August 2004

STANDARD OPERATING PROCEDURES

SOP: 1729

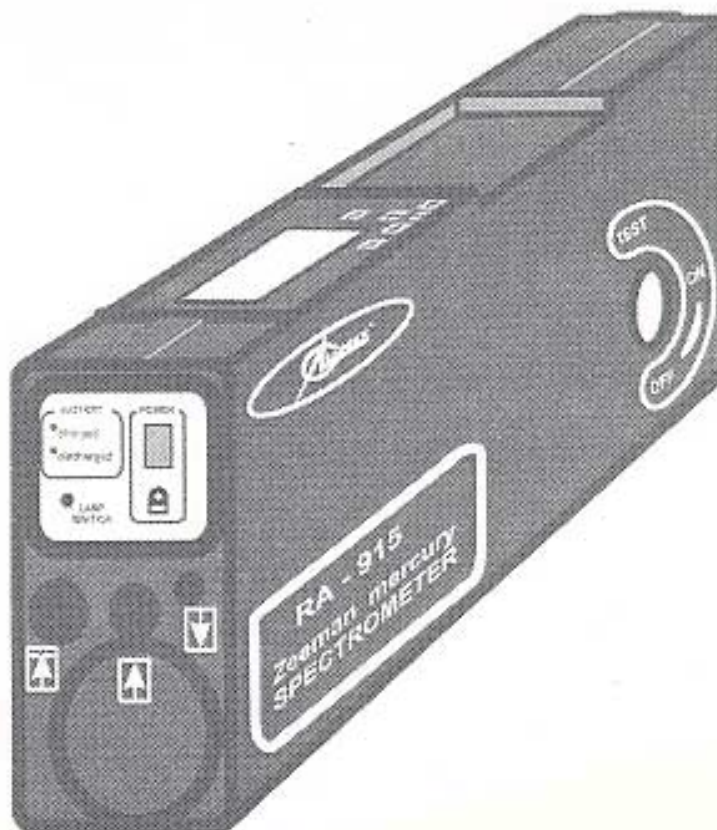
PAGE: 16 of 21

REV: 0.0

DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

FIGURE 1. View of the RA-915⁺ Analyzer





STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 17 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915+ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

APPENDIX B

Maintenance, Troubleshooting, Storage, and Transportation

SOP #1729

August 2004



STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 18 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

MAINTENANCE, TROUBLESHOOTING, STORAGE, AND TRANSPORTATION

All the maintenance operations should be recorded in the analyzer log. Daily inspection is performed in the work place and involves visual inspection of the analyzer and the serviceability check (TEST mode).

Routine preventive maintenance must be performed and includes the following:

- Checking screws and fasteners for covers;
- Checking condition of connectors and cables;
- Replacing the air intake dust filter every three months (located in the air inlet on the front wall of the base unit, see Section 7.1.1); and
- Replacing the built-in absorption filter every six months (located in the right-hand inlet on the front wall of the base unit, see Section 7.1.1).

For short-time storage, keep the analyzer indoors at an ambient air temperature of 5-40 degrees Celsius (°C) with the relative humidity not exceeding 98 % at 30°C. The air should not contain any corrosive impurities. Charge the analyzer battery fully prior to storage. For long-time storage, place the RA-915⁺ in a polyethylene case.

Pack the analyzer securely in a suitable case prior to shipment. When shipping the unit, observe appropriate shipping transportation regulations. Allow at least ten hours at normal temperature before unpacking the analyzer, if it has been transported at temperatures below the freezing point.

All RA-915⁺ repairs as well as annual preventive maintenance and calibration must be performed by authorized personnel. The unit must be shipped to the OhioLumex Co. factory service center for repairs and annual preventive maintenance. User troubleshooting for minor malfunctions is summarized in the table below:

STANDARD OPERATING PROCEDURES

SOP: 1729
 PAGE: 19 of 21
 REV: 0.0
 DATE: 08/20/04

OPERATION OF THE LUMEX RA-915⁺ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

MAINTENANCE, TROUBLESHOOTING, STORAGE, AND TRANSPORTATION (continued)

Symptoms	Possible Cause	Troubleshooting Action
When switching the analyzer on, segments of the indication and display unit display (palm monitor) are not highlighted.	Power Cable is out of order. Display unit cable is out of order. Battery is discharged.	Repair/replace the power cable. Repair/replace the display unit cable. Charge the battery.
The * symbol in the MAIN MENU does not go out when the "Lamp Ignition" button is pressed: - optical switch in position I - optical switch in position II - optical switch in position III	Battery is discharged. Operation is possible only with attachments. The single-path cell is contaminated, compartment windows are contaminated, or foreign objects are in the compartment. Multi-path cell is contaminated.	Charge the battery. Set the optical switch to position II or III. Remove the single-path cell, check if compartment windows are clean, and ensure that there are no foreign objects inside the compartment. Clean the multi-path cell (see Lumex RA-915 ⁺ User's Manual).
The battery discharge indicator (red) glows for some time and then goes out when the analyzer is switched on.	The battery is fully discharged.	Charge the battery.
In TEST mode, the relative deviation (R) exceeds the specification (25 %).	Spectral lamp is not switched on. Test cell switch is in idle position (OFF). Test cell is out of order. Absorption filter has failed.	Press the lamp ignition button. Set the test cell switch to working position (ON). Shake the test cell several times using the (ON/OFF) switch. Replace the filter.



STANDARD OPERATING PROCEDURES

SOP: 1729
PAGE: 20 of 21
REV: 0.0
DATE: 08/20/04

OPERATION OF THE LUMEX RA-915+ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

Test Cell Mercury Concentration vs. Temperature
SOP #1729
August 2004

STANDARD OPERATING PROCEDURES

SOP: 1729
 PAGE: 21 of 21
 REV: 0.0
 DATE: 08/20/04

OPERATION OF THE LUMEX RA-915+ ANALYZER FOR MEASURING MERCURY VAPOR CONCENTRATIONS IN AMBIENT AIR

TEST CELL MERCURY CONCENTRATION VS. TEMPERATURE

T (°C)	S _k	T (°C)	S _k
1	320	21	1650
2	347	22	1791
3	377	23	1943
4	409	24	2109
5	445	25	2291
6	482	26	2485
7	524	27	2698
8	568	28	2929
9	616	29	3180
10	669	30	3451
11	727	31	3750
12	788	32	4060
13	856	33	4410
14	929	34	4790
15	1008	35	5200
16	1095	36	5640
17	1188	37	6130
18	1290	38	6650
19	1400	39	7220
20	1519	40	7835